



ACQUISITION AND  
TECHNOLOGY

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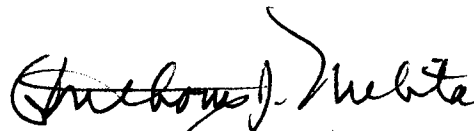
MEMORANDUM FOR U.S. MISSION TO NATO, ARMAMENTS COOPERATION DIVISION  
(ARMY ARMAMENTS OFFICER), PSC 81, APO AE 09724

SUBJECT: SUBMISSION FOR APPROVAL OF DRAFT AOP-31 (EDITION 1) –  
“DEMOLITION MATERIEL: DESIGN PRINCIPLES”

Reference document, PFP(CPG-S/3)D/16, 07 March 2000, SAB.

The U.S. Armed Forces approve the publication of AOP-31 with one comment. Page A-2, item [c11], second line, delete “AECTP-400: Climatic Environmental Tests” and replace with “AECTP-500: Electrical Environment Tests”.

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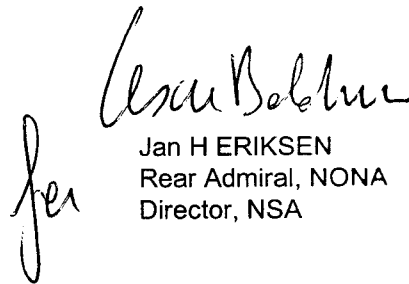
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NATO LETTER OF PROMULGATION

May 2002

1. AOP-31 - (Edition 1) - DEMOLITION MATERIEL; DESIGN PRINCIPLES is a NATO/PfP UNCLASSIFIED publication. The agreement of nations to use this publication is recorded in STANAG 2818.
2. AOP-31 (Edition 1) is effective upon receipt.

  
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NATION	SPECIFICATION RESERVATIONS

RECORD OF CHANGES

Change Date	Date Entered	Effective Date	By Whom Entered

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## INTRODUCTION

### 1. Purpose

The purpose of this publication is to provide principles and criteria applicable to the safety and suitability for service in the design of demolition materiel.

### 2. Scope

2.1 This AOP is related to STANAG 2818, which covers two AOPs:

- a. AOP-31: Demolition Materiel, Design Principles, and
- b. AOP-32: Demolition Materiel, Assessment and Testing of Safety and Suitability for Service.

2.2 A functional description of demolition materiel is included in this AOP. AOP-32 comprises detailed guidelines for the assessment and testing of safety and suitability for service based on the principles given in this AOP.

### 3. Reference Documents

Documents referred to in this publication are listed in Annex A.

### 4. Terminology

The terms and definitions published in AAP-6 [a9] and AOP-38 [a10] are applicable.

### 5. Application

5.1 As required by STANAG 2818, the design principles and criteria for safety and suitability for service laid down in this AOP shall be applied to all new demolition materiel. The determination and decision if a munition is classified as "new" are to be performed by the formally designated National Authority (see STANAG 2818 Annex A), using the definition of "new demolition materiel" in STANAG 2818.

5.2 Implementation of this AOP with regard to the design of new demolition materiel comprises of:

- a. the application of the requirements outlined in Annex B to this AOP and other critical requirements identified as the result of functional and safety analyses; and
- b. assessment of its compliance with this AOP, justified by theoretical analysis validated by testing, in accordance with AOP-32.

Note: Requirements marked "shall" are mandatory; requirements marked "should" are optional.

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6. Other Use

The use of this publication is not limited to design assessments of safety and suitability for service. It also provides guidance for the development process, growth of reliability and safety, establishment of maintenance procedures and munition surveillance programs, and evaluation of modifications of previously qualified demolition materiel.

7. Restrictions

- 7.1 Modifications to a demolition system carried out to improve reliability or performances of the materiel shall not affect safety.
- 7.2 Compliance of the materiel with this publication does not mean that safety and reliability are ensured under all conditions.

DEMOLITION SYSTEMS DESCRIPTIONS, DESIGN OBJECTIVES AND REQUIREMENTS

8. Subject materiel

8.1 Demolition Systems

- 8.1.1 Demolition systems comprise all hardware and software necessary to execute a demolition mission. In relation to the complexity and the varieties of these systems and the need to adapt their deployment to each mission, demolitions systems are normally subdivided into subsystems and parts of subsystems. Such subdivision is summarized schematically in Table 1 below.

Table 1: Subdivision of a Demolition System

DEMOLITION SYSTEM			
FIRING SYSTEM			DEMOLITION CHARGE(S)
FIRING CONTROL SYSTEM	FIRING CIRCUIT		
	FIRING STIMULUS RELAY SYSTEM (non-explosive circuit)	DETONATION RELAY SYSTEM (explosive circuit)	
	FUZE OR FUZING SYSTEM		

8.1.2 When deployed, a demolition system normally consists of:

- a. one or more demolition charges, and
- b. a firing system, for safe firing of the charges.

A more detailed description is given in the following paragraphs.

8.1.3 In general, demolition subsystems are groups of linked components capable of performing a unique sub-function within a demolition system. Demolition charges, detonation relay systems, firing stimulus relay systems and firing control systems are major subsystems. An overview of these subsystems and their constituent elements is given in the subparagraphs below. Certain parts of these subsystems may be integrated within a fuzing system.

8.1.4 For example, in the case of the usual electric firing system, the electric power source is the firing control system, and the electric firing cables are the firing stimulus relay system. The detonators, detonating cords and boosters or connecting charges form the detonation relay system and the main charges are the demolition charges.

8.1.5 In many cases, demolition subsystems, sets of accessories and tools are supplied as kits in one package. Examples are: demolition kits, rapid cratering systems (charges and accessories), one-shot-two-steps demolition charges (pre-assembled cratering systems).

## 8.2 Firing Systems

8.2.1 Subsystems. A firing system may consist of the following subsystems (see Table 1):

- a. A firing control system which accepts the firing command and produces a firing stimulus or a command signal. A firing control system requires a manual action. However, it may include an automatic function e.g., an anti-disturbance device, a remote control and/or a timing delay. It may also include a circuit tester.
- b. A firing stimulus relay system which:
  - (1) transmits the firing stimulus from the firing control system to the detonation relay system to initiate the explosive train or
  - (2) transmits the firing command signal from the firing control system to a fuzing system,

to enable firing at a safe place and distance. Relay of the firing stimulus or firing command signal is effected by means of an electrical circuit, glass fibres, or by a transmitter-receiver system. It may comprise relay boxes, a transmitter and one or more sensors. It constitutes the non-explosive part of the firing circuit.
- c. A detonation relay system, which conveys the detonation to the demolition charge(s). It may consist of lengths of detonating cord or shock tube (connected by connectors, clips, tape, etc.), leads, delay elements such as safety fuze, detonators, boosters. It constitutes the explosive part of the firing circuit.
- d. A fuzing system, which accepts the command signal, converting the command signal into initiation of the demolition charge. It may be attached to a detonation relay system, or directly to a demolition charge, incorporating the detonation relay functions. It may also contain a delay feature.

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8.2.2 Components. An igniter, an initiator, or a fuzing system may constitute a part of, or be the complete firing system.

8.2.3 Types of firing systems. Known types are:

- a. Pyrotechnic firing systems, consisting of a firing control system, usually an exploder (blasting machine), an electrical or mechanical (percussion) igniter/fuze or match, one or more lengths of safety fuze, and connectors to connect their ends. The safety fuze line is connected to a non-electric detonator (pyrotechnic initiation).
- b. Shock tube firing systems, consisting of a mechanical (percussion) or electrical initiator, one or more lengths of shock tube and inert connectors (distributors) to interconnect shock tubes. The end of each shock tube line is connected to a pyrotechnic detonator.
- c. Electrical firing systems, consisting of an exploder (blasting machine) and one or more firing cables connected in series by twisting, or by means of connectors. The end is connected to an electric detonator. To ensure safety and reliability, the firing circuit is normally tested for electrical resistance or continuity.
- d. Optic firing systems, which may be developed in the future.
- e. Radiation firing systems (RF, high powered laser). A transmitter produces a coded signal by means of a firing signal generator, which is transmitted to a receiver which is either connected to an electrical firing system or contains an integral detonator.

### 8.3 Fuzing Systems

8.3.1 Known types of fuzing systems are: mechanical, electronic, with or without timing, with or without anti-disturbance feature, intended for underwater or land use, or multi functional.

8.3.2 Fuzing systems may incorporate:

- a. a signal receiver associated with the transmission system of the firing command;
- b. a unit for processing the signal (discrimination, conversion into firing energy);
- c. a safety and arming unit;
- d. an anti-disturbance capability;
- e. a detonation relay system;
- f. a self-neutralization system;
- g. a self-destruction system.

### 8.4 Detonation Relay Systems

8.4.1 The principal elements of a detonation relay system are:

- a. Detonators: Devices intended either to initiate the next downstream part of the detonation relay system or directly a demolition charge, upon receipt of a specific stimulus: electrical, percussion, heat, etc. The detonator may be a part of a fuze.

The explosive train within a detonator usually is in line. If several electrical detonators are connected in series to the electrical circuit, and the time to start of ignition (irreversible reaction of the squib composition) of one or more squibs is longer than the shortest reaction time (the time to interruption of the circuit by detonation) of one of the detonators, the non-ignited detonators will fail.

- b. Detonating cord: Cord intended to transmit a detonation over a relatively large distance to another detonating cord, a booster, a lead or a main charge. The detonating cord may itself serve as a main demolition charge, for cutting small targets. Detonating cords produce a high order detonation ( $\geq 5900$  m/s) dependent on the characteristics of the explosive material.
  - c. Shock tube: Tube containing a smaller quantity of explosive, with the explosive applied onto the inside of the tube. It produces a lower order detonation ( $\approx 2000$  m/s) and requires the use of a detonator (which is initiated by the shock wave from the tube), and sometimes a booster charge to set off a demolition charge.
  - d. Leads: explosive elements intended to transmit a detonation or a deflagration in an explosive train, such as the secondary charge of a detonator. In demolition relay systems, leads may be a part of fuzing systems. Explosive connectors, boosters, primer delays and detonating cord may also have a lead function.
  - e. Boosters: Leads or charges reinforcing a detonation.
  - f. Explosive connectors: The means of connecting successive elements of a detonation relay system and/or the main charges. They may have a booster function.
  - g. Other connecting aids: Clips, non-explosive connectors, tape, adapters, etc. for connecting pieces parts of the detonation relay system.
  - h. Insulators: Intended for protection of detonating cord or safety fuse ends against moisture ingress (e.g. lacquer), or for electrical insulation (tape).
- 8.4.2 With the exception of inert connecting aids (tape and lacquer for isolation, etc.), the elements forming a detonation relay system commonly consist of an explosive charge and an envelope (a casing assembly or a tube).
- 8.4.3 An intermediate explosive charge picks up the explosive reaction from the upstream element and initiates the downstream element.
- 8.4.4 The envelope has the following functions:
- a. to support the transmission of the detonation by means of good connections, etc.;
  - b. to enable elements to be easily and reliably connected;
  - c. to enable the store to be handled safely and easily;
  - d. to assist in identification (colour and markings);
  - e. to protect the charge from influences from the environment; and
  - f. to protect the environment (e.g., prevention of human contact with toxic materials).

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## 8.5 Demolition Charges

Demolition charges may be in the form of: demolition blocks, plastic (slab) explosive charges, shaped charges (hollow - cutting - and other formed charges), line charges, cratering charges, rapid cratering charges (a set of cratering charges or combinations of charges in a common packaging for preparation at the site of use and fuel-air explosives).

## 8.6 Ancillary Materiel

Some types of ancillary demolition materiel are:

- a. test sets: Devices which are supplied with the firing system or the firing control system and used to verify the availability and the safety of the system;
- b. tools: The use of specific tools may be prescribed for certain tasks. The use of similar commonly available tools may be excluded for safety reasons;
- c. launchers, e.g., for mine clearance systems, to lay flexible line charges over a mine field. A special projection system may be needed.

## 9. Function and Performance

### 9.1 Purposes of Demolitions

The principal objectives of demolition operations are the destruction of targets (buildings, roads, bridges, equipments, man made obstacles), clearance (e.g., breaching mine fields or natural obstacles) and the creation of obstacles (e.g., craters).

### 9.2 Functional Requirements

9.2.1 The main functional requirements for a demolition system are as follows:

- a. to provide sufficient explosive power to achieve the purpose: blast, hollow charge effect, spall or "knife" to destroy, perforate or cut a target;
- b. other than in the case of an anti-disturbance device, each demolition charge is to be fired at the appropriate moment by human control. This may include the setting of delay timer(s). Firing may take place at any time, even a long time after installation of the demolition;
- c. to fire the demolition charge safely, following an operating procedure and from a place which meet safety requirements, depending on the danger area laid down for the type of demolition and on tactical/operational considerations;
- d. to be suitable for rapid, secure and safe deployment and installation. In most cases, the system is set up by hand. Some demolition charges, e.g., line charges, may be launched by a projection system.

9.2.2 These functional requirements dictate the modular construction of most demolition systems, other design criteria, and their typical life cycle.

### 9.3 Functional Analysis

- 9.3.1 To determine whether all functional requirements are adequately covered by the design, common reliability techniques are available: functional trees, FMECA, etc. See AOP-15 [a6] and AMRP-1 and -2 [a5]. The design requirements, outlined in this publication are not intended to replace functional analyses.  
Generally, reliable functioning of each intermediate element within the system requires the following (the list is not exhaustive):

- a. Appropriate output (functional stimulus) to effect the next higher function (downstream). This means, that a specific output of a donor element needs to be ensured at a minimum level S: the "minimum output level".
- b. Sufficient sensitivity/receptivity to react on the input received: the output of the next lower function (upstream). This means, that the reliable initiation of an acceptor element needs to be ensured at a given level T for a specific input, the "all-function level" or "all-fire level".
- c. Effective transmission and/or processing of input to output. This relates to the internal functions of an element. These may include: reinforcement (e.g. of a detonation by a booster) or conversion (e.g., of an electric current into detonation in an electric detonator, or of a flame into detonation in a pyrotechnic detonator).
- d. Satisfactory interface reliability. This means, that given an output S of the donor and an all-function level T of the acceptor, the limiting degradation D of the stimulus in the interface be:  $D < S - T$ . The output of the donor must be greater than the all-function level of the acceptor, taking into account the interface effects. D, S, and T must be defined for a particular type of stimulus (mechanical energy, heat, electric current, etc.). If the measurements of S and T are representative of the real values of S and T in the system configuration, comprising the losses at the interface, D may be neglected.

- 9.3.2 The main causes of failure likely to lead to a reduction in safety and/or reliability of the demolition system are:

- a. design errors (e.g. a minimum output level inferior to the all-fire level of a downstream element);
- b. non-conformance of any element with its design (production failure, degradation, ageing);
- c. incorrect configuration of any element of the system;
- d. incorrect interfaces;
- e. malfunctioning of any demolition store or malfunctioning of the system as a whole;
- f. extreme environmental conditions, likely to exist during its life cycle;
- g. human failures.

### 10. Safety

- 10.1 A number of techniques are available in support of design safety assessments: Hazard or Risk analyses, Fault Tree Analysis (FTA), etc. See AOP-15 [a6]. The design safety principles outlined in this AOP do not eliminate the need for a full design safety assessment of demolition materiel prior to its acceptance into service.

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10.2 The following events shall be classified as Hazard Severity Category I and the acceptability should be assessed in accordance with AOP-15 [a6]:

- a. unintended (premature) functioning of one or more stores during storage, transportation, maintenance, handling, installation of a demolition;
- b. delayed functioning of charges during dismantling of a demolition after execution of a demolition or during disposal;
- c. serious unwanted secondary effects of intended functions which could lead to death of friendly personnel, loss of assets, or extensive contamination or damage to the environment, e.g., during disposal of obsolete stores or during exercises.

10.3 Causes of hazardous events are to be sought, for example, in:

- a. design errors (e.g. use of too sensitive explosives, vulnerable construction);
- b. non-conformance of the munition with its design (production failure, degradation, ageing);
- c. incorrect configuration of any element of the system;
- d. incorrect interfaces;
- e. malfunctioning of a safety feature;
- f. malfunctioning of an element or the system as a whole;
- g. extreme environmental conditions, likely to exist during its life cycle, including credible accidental conditions which are likely to occur during its life cycle (cf., STANAG 4439 [a8]);
- h. human failures.

11. Environment

11.1 General

Reliability and safety shall be ensured under all environmental conditions likely to be encountered. In accordance with AOP-15 [a6], AECTP-100[a5] and ARMP-1 [a5], both the life cycle events and the anticipated service environment of the demolition materiel will need to be defined.

11.2 Anticipated Service Environment

11.2.1 The environmental factors (service environment), acting on the demolition materiel normally do not differ from those encountered by all combat materiel. However, demolition stores and (sub)systems are subjected to some particular environmental conditions:

- a. the elaborate and wide-spread deployment of the system and its exposure to the environment makes it more vulnerable to the effects of lightning, wind, icing, etc. and battlefield conditions such as weapon fire or explosions;
- b. climatic conditions may have an effect on the target, e.g., freezing of ground, which may cause failure;
- c. the considerable handling during deployment increases the risks of human failures.



### 11.3 Environmental Norms

- 11.3.1 When a munition is subjected to the anticipated service environment, that is to all natural and induced conditions within their extreme limits specified for its entire life cycle, the requirements for suitability for service (reliability, availability, maintainability) and for safety shall be met. Thus the munition shall be safe and maintainable during its storage life and ready and safe for deployment and use during its operational life and safe for demilitarization, destruction and disposal.
- 11.3.2 In addition, when the munition is subjected to a more severe environmental conditions or to accidental but credible conditions, such as fire, traffic accidents, bullet or fragment attack and other threats described in STANAG 4439 [a8];
- a. it should not produce the critical reactions, specified by the National Authorities; and
  - b. unexploded munitions and components thereof shall be safe for destruction and disposal.
- 11.3.3 Environmental criteria with regard to safety may be more severe than with regard to suitability for service. Specific environmental aspects are detailed in Annex B section 6. These are minimum standardized conditions and not intended to replace environmental analyses.

### 12. Standard Requirements

- 12.1 Standard requirements for safety and suitability for service of new demolition materiel are detailed in Annex B. These requirements must be met under the anticipated service environmental conditions.
- 12.2 It should be noted however that these requirements do not guarantee reliability and safety for all types of demolition materiel during their entire service life. Therefore, compliance with these requirements does not exclude the necessity of full analyses as outlined in sections 9, 10 and 11 above.
- 12.3 In general, the design and development process should be conducted following AQAP-110 [b1] or equivalent international or national documents.



**REFERENCE DOCUMENTS**

This annex comprises major sources and background information for this AOP.

**a. General reference documents**

- [a1] STANAG 2818: Demolition Materiel: Design, Testing and Assessment (Cover STANAG for the AOP)
- [a2] AOP-32: Demolition Materiel, Assessment and Testing of Safety and Suitability for Service.
- [a3] STANAG 4123 and AASTP-3: Methods to Determine and Classify the Hazards of Ammunition; Manual for -
- [a4] STANAG 4170, Principles and Methodology for the Qualification of Explosive Materials for Military Use
- [a5] STANAG 4174, ARMP-1 and ARMP-2: NATO Requirements for Reliability and Maintainability; General Application Guidance for -
- [a6] STANAG 4297 and AOP-15: Guidance on the Assessment of the Safety and Suitability for Service of Munitions for NATO Armed Forces
- [a7] STANAG 4370: Environmental Testing and AECTP-100: Guidelines on Management Planning.
- [a8] STANAG 4439: Policy for Introduction, Assessment and Testing for Insensitive Munitions (MURAT) and AOP-39 (Guidance on -)
- [a9] AAP-6: NATO Glossary of Terms and Definitions (English and French)
- [a10] AOP-38: Glossary of Terms and Definitions Concerning the Safety and Suitability of Munitions, Explosives and Related Products.

**b. Documents Covering Munitions Design**

- [b1] AQAP-110: Allied Quality Assurance Publications/- Design, Development and Production.
- [b2] STANAG 4147: Chemical Compatibility of Ammunition Components, Explosives and Propellants
- [b3] STANAG 4187 and AOP-16: Fuzing Systems - Safety Design Requirements/- Guides
- [b4] Draft STANAG 4238: Design Principles for Hardening Munitions/Weapon Systems Against Electromagnetic Environment
- [b5] STANAG 4404: Safety Design Requirements and Guidelines for Munition Related Safety Critical Computing Systems
- [b6] STANAG 4497: Hand-emplaced Munitions, Principles of Safe Design
- [b7] STANAG 4518: Safe Disposal of Munitions, Design Principles and Requirements, and Safety Assessment.
- [b8] Convention on the Marking of Plastic Explosives for the Purpose of Detection; Montreal, 1 March 1991

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**c. Documents Covering the Environment**

- [c1] STANAG 1307, Maximum NATO Naval Operational Electromagnetic Environment Produced by Radio and Radar.
- [c2] STANAG 2895: Extreme Climatic Conditions and Derived Conditions for Use in Defining Design/test Criteria for NATO Forces Materiel.
- [c3] STANAG 2914 and AECF-1: Mechanical Environmental Conditions to Which Materiel Intended for Use by NATO Forces Could Be Exposed.
- [c4] STANAG 4145 and AEP-4: Nuclear Survivability Criteria for Armed Forces Materiel and Installations
- [c5] STANAG 4234, Electromagnetic Radiation (Radio Frequency) 200 KHz to 40 GHz Environment Affecting the Design of Materiel for Use by NATO Forces.
- [c6] STANAG 4235, Electrostatic Environmental Conditions Affecting the Design of Materiel for Use by NATO Forces.
- [c7] STANAG 4236: Lightning Environmental Conditions Affecting the Design of Materiel for Use by NATO Forces.
- [c8] STANAG 4240: Liquid Fuel Fire Tests for Munitions
- [c9] STANAG 4241: Bullet Attack Tests for Munitions
- [c10] STANAG 4242 and AOP-34: Vibration tests for munitions carried in tracked vehicles.
- [c11] STANAG 4370: Environmental Testing; AECTP-200: Definitions of Environment; AECTP-400: Climatic Environmental Tests; AECTP 300: Climatic Environmental Tests; AECTP-400: Mechanical Environmental Tests.
- [c12] STANAG 4375: Safety Drop Munition Test Procedures
- [c13] STANAG 4382: Slow Heating Tests for Munitions

## DESIGN REQUIREMENTS

### INTRODUCTION

The requirements for design of demolition materiel are given as mandatory requirements or as recommendations.

#### **1. GENERAL REQUIREMENTS**

**R1.1: Demolition systems, subsystems, stores and accessories shall be designed to achieve and maintain the desired degree of overall system reliability, availability, maintainability and safety in compliance with requirements defined in the staff requirements during their logistic and operational life cycle.**

R1.1.1: Evidence will be required from reliability and safety (S3) analyses and trials defined in accordance with AOP-15 [a6] and ARMP-1 [a5]. These will take into account the entire system, and all permissible configurations. Each component should be considered individually with special attention to the interfaces between them. The hazard analysis should be conducted in accordance with AOP-15 [a6] and, if safety critical computing systems are identified, these shall be designed in accordance with STANAG 4404 [b5]. Cf. §9 and §10 of main text of the AOP.

R1.1.2: Demolition systems, sub-systems and materiel shall be designed to ensure and maintain the required degree of reliability and safety during their entire life cycle (c.f., R6.2.1). Moreover, safety shall be ensured and maintained under all normal and extreme, but credible, environmental conditions, as stated in R6.2.2.

R1.1.3: Demolition system reliability, including availability and maintainability should be at least  $1 - 10^{-2}$ . The value, applicable for each element of the system should be derived from the required level for the complete system in its most complex but likely deployment configuration, according to the user instructions for deployment.<sup>1</sup>

R1.1.4: Demolition systems, subsystems and elements shall be exempt from risk levels 1 and 2 as defined in AOP-15 [a6]. However, risk level 2 may be tolerated during deployment and use. The acceptable risk level for each element shall be compatible with the required level for the complete system in its most complex but likely deployment configuration, according to the user instructions for deployment.<sup>2</sup>

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<sup>1</sup> The "most complex situation" with regard to reliability and safety is to be defined in the user instructions which must be an integral part of the product definition. Prescribed redundancies in the demolition system lay-out may be taken into account.

<sup>2</sup> The "most complex situation" with regard to reliability and safety is to be defined in the user instructions which must be an integral part of the product definition. Prescribed redundancies in the demolition system lay-out may be taken into account.

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**R1.2: The safety of demolition materiel (system, subsystems and components) shall result from the safety of each element and the (sub)systems, the possible interfaces and the specified system configurations, and this in the worst case conditions of the materiel, environment and use during the entire service life.<sup>3</sup> (C.f., AOP-15 [a6])**

R1.2.1: The safety of all individual demolition stores shall be ensured during their entire life cycle (logistic life, operational life and disposal).

R1.2.2: The (sub)system safety shall be ensured during deployment and installation of the demolition, taking into account all possible handling, situations and configurations.

R1.2.3: Demonstration of the safety level shall be based on analyses, documented safety data and testing.

R1.2.4: Safety analyses should include:

1. effects of failures on the environment;
2. fault tree and hazard analyses (FTA, HA, HAZOP);
3. failure mode and criticality analysis (FMECA);
4. sneak analyses and
5. human factors.

**R1.3: The reliability of a demolition system shall result from the reliability of the function of each element and subsystem and the of transfer of stimuli over all interfaces between the elements and this in the expected deployment and use conditions.**

R1.3.1: Sufficient confidence is required to demonstrate that the lowest output level of each donor element which is part of the system exceeds the all-function (all-fire) level of all acceptor elements which can be connected to it downstream.

R1.3.2: If the required input level (sensitivity) of a receptor has a maximum and a minimum, the output level of the donor shall be between these two limits with a level of confidence compatible with the requirements for safety and reliability.

R1.3.3: The output requirements of the donor elements shall be based on the same physical characteristics as the input requirements of the receptor elements.

R1.3.4: For assessment of the (sub)system reliability, any redundancy will be taken into account.

**R1.4: The interfaces of all demolition stores and accessories which are parts of the system, mounted in any possible designed configuration, shall ensure reliable function and safety during deployment and use.**

R1.4.1: The reciprocal distance and position of the elements within a pyrotechnic or an explosive train shall be in accordance with defined limits to ensure transmission of the combustion or detonation at the required all-fire levels

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<sup>3</sup> The worst case conditions are the most unfavourable configurations, which are possible in accordance with data package (e.g. physical characteristics, connections, distances), environmental profile and the user instructions (e.g., most complicated firing circuit).

R1.4.2: The electrical or other connectors transmitting signals or energy shall be designed to prevent erroneous assembly, in particular to preclude wrong connections which could not be discovered by the prescribed testing of the deployed system.

R1.4.3: Mechanical connections shall be sufficiently strong and watertight to prevent loosening due to handling and other environmental factors and also to prevent moisture ingress to explosive or pyrotechnics fillings or electrical circuits and connections or the connectors between elements of the system.

R1.4.4: Demolition charges should be provided with a fixture to maintain the detonator in an appropriate position, which ensures the right initiation of the booster or the main charge.

**R1.5: A single (materiel) fault or failure (of any function) in the system shall not be able, on its own or in combination with one other fault or failure, to result in functioning of one or more explosive stores within the system during its deployment, readiness time or dismantling.**

**R1.6: The deployed demolition system shall be fail-safe.**

If one or more specific safety features of the system (e.g., arming delay, deactivation) fail, no explosive stores shall function. See also R3.4.

**R1.7: All demolition stores and accessories shall be designed so that any human failure:**

- **will in no way compromise safety and**
- **degradation of reliability is minimized.**

R1.7.1: The user instructions are to be considered as a part of the design, therefore they shall be as clear and simple as possible.

R1.7.2: The design of articles supplied as demolition systems:

- a. shall preclude unsafe assembly of the various elements; and
- b. should preclude assembly of the elements affecting reliable function.

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**R1.8: Demolition (sub)systems, stores and accessories shall be designed for rapid, reliable and safe deployment and installation. See also R1.7.**

R1.8.1: The distance from firing point to the demolition charges shall be compatible with the systems safety provisions.

R1.8.2: Human factors (eg. ergonomics) shall be taken into account in meeting operational and safety requirements in the design.

R1.8.3: The user instructions shall contain all necessary procedures to ensure safe handling and reliable and safe functioning.

R1.8.4: If specialist tools are required for deployment and dismantling of the demolition system, these shall be specified in the user instructions, and their purpose and mode of use shall be described.

R1.8.5: The design and the users instructions of a demolition system shall preclude that a remote controlled or delayed timing initiation device can arm the system before the time needed for all personnel to withdraw to a safe distance from the explosive store(s) has elapsed.

**R1.9: All explosive demolition material shall be designed to permit their safe re-use or disposal in accordance with STANAG 4518 [b7].**

R1.9.1: Normal use of demolition materiel shall not create unacceptable chemical or other pollution of the environment (soil, water, air).

R1.9.2: At any stage of the operational phase, and in particular:

- after a total or partial demolition failure (remaining unexploded stores),
- if a deployed system has been damaged (eg. by fragment hits) or
- after cancellation of a demolition mission, safe dismantling and/or disposal of undamaged and damaged stores shall be practicable.

R1.9.3: The unused demolition materiel remaining after deployment should be capable of safe re-use unless otherwise specified.

R1.9.4: Demilitarization and disposal of demolition materiel (disassembly, destruction) at the end of its service life shall be possible without unacceptable risks to personnel or to the environment. Waste shall be kept to a minimum.

R1.9.5: All materials used in the construction of demolition materiel and their packages shall be safely recyclable or safely disposable with minimal pollution of the environment. The use of toxic materials should be avoided.

**R1.10: Demolition materiel design shall comply with STANAG 4497 (Hand Emplaced Munitions [b6]), as applicable to demolition materiel.**

**R1.11: The user instructions shall be accurate and clear in order to achieve safe handling and use of the materiel and to avoid human failures.**



## **2. DEMOLITION STORES AND ACCESSORIES**

**R2.1: Maintainability of demolition stores, accessories and equipment shall ensure the required degree of reliability and safety.**

R2.1.1: A system of periodic surveillance and maintenance shall be defined.

R2.1.2: If certain elements have a limited service life, the expiring date shall be marked on the item and/or its package. e.g., batteries.

**R2.2: Demolition charges shall perform (destructive capability or other) according to the applicable NATO or national staff requirements.**

**R2.3: All explosives used in demolition stores shall meet and maintain safety and performance requirements.**

R2.3.1: All explosives used in demolition stores shall be qualified in accordance with STANAG 4170 and have passed successfully the qualification testing in accordance with AOP-7 [a4].

R2.3.2: The explosive compositions and materials shall be free from the risk of formation of unduly sensitive or dangerous compounds under the specified conditions. See STANAG 4147 [b2].

R2.3.3: Materials which could contribute to the formation of more volatile or more sensitive compounds shall be treated, located or enclosed to prevent the formation of a hazardous compound.

R2.3.4: The explosives and other materials used should possess and maintain the required characteristics of strength, and dimensional and chemical stability in accordance with STANAG 4147 [b2] under all specified conditions, to ensure their safety and suitability for service.

R2.3.5: Solid demolition charges, stores and accessories should be designed to maintain their shape and size throughout the life cycle.

R2.3.6: Any detection agent added to plastic explosives, to comply with the Convention of Montreal [b8], shall not affect the safety and functional characteristics of the explosive.

**R2.4: Demolition stores shall have been classified (storage - transportation) in accordance with STANAG 4123 [a3].**

## **3. FIRING SYSTEMS**

**R3.1: Accidental events or actions shall not cause firing of the demolition system.**  
(See also R1.7).

R3.1.1: For firing control systems, two different and independent actions are an acceptable solution (for example, a switch to charge a firing capacitor and a separate firing switch far enough apart on the unit so that both hands have to be used for firing). To connect wires to an exploder or a battery does not constitute an independent act.

R3.1.2: In electrical initiated systems, the use of 2 switches, connected in series, with the proviso that the 2 switches are of different design to avoid the possibility of common cause failure, is acceptable.

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R3.1.3: The exploder shall be equipped with a detachable firing lever, safety key or other device, necessary to release the firing stimulus. However, if the exploder can be hand-carried, this requirement may be waived. The user instructions shall contain a procedure such that the person who is responsible for the final preparation of the demolition retains the lever, key or other safety device on his person.

**R3.2: Electrical firing circuits and apparatus shall be designed to minimise the unwanted effects of electromagnetic radiation (EMR), electrostatic discharge (ESD), electrical transient and steady state electromagnetic interference (EMI), lightning and nuclear weapon effects.**

R3.2.1: The no-fire thresholds of the detonators, initiators and/or igniters shall be above the stimuli which are likely to affect them during their life cycle. Note: STANAG 4238 [b4] will provide guidance on EED-protection.

R3.2.2: The safety margin between the no-fire threshold power or energy of any electro-explosive device (EED), which initiates the explosive train or a main charge, and the maximum power or energy induced by electrical or electromagnetic interference into its integrated firing circuit shall in accordance with international and national safety regulations, and should be as large as possible.

R3.2.3: Electrical and electronic (sub)systems and accessories should be assessed and/or tested for electric and electromagnetic compatibility in accordance with the requirements concerning electric and electronic materiel. Ref. [c1] and [c4] - [c7].

**R3.3: All systems shall, where possible, include a method whereby the operator can disarm, render safe and then lift or recover the store(s) at any time after the firing circuit has been committed-to-arm, unless specifically excluded in the requirement.**

**R3.4: A firing control system shall not be able to transmit any signal at its interfaces beyond the no-fire threshold of the system, if one or more system functions fail.**

R3.4.1: An exploder shall not be able to produce a firing current if the safety locking mechanism is defective, or if the safety key is missing.

R3.4.2: The connecting poles of an exploder shall be completely discharged after each firing.

**R3.5: In deployed configuration, it should be possible, without degrading safety, to establish whether the system is armed and the status of safety switches.**

R3.5.1: The indication used shall avoid confusion or ambiguity with other indications with respect to the state of the system.

R3.5.2: Red should be used to indicate a safety related failure in the system.

**R3.6: A firing control system shall not be able to produce a hazard to the user when used in accordance with the user instructions.**

R3.6.1: Touching of the poles of an exploder at the moment of firing shall be prevented by its construction.

R3.6.2: The firing control system shall be designed so that the user is protected from any form of dangerous radiation (e.g., a laser beam). In addition, special procedures laid down in the user instructions may be necessary.

**R3.7: The firing system shall be designed to ensure reliable and safe function of all detonators/initiators of the deployed demolition system in the most unfavourable configuration which is in accordance with the user instructions.**

R3.7.1: The capacity of an exploder (blasting machine) shall be sufficient to initiate all specified detonators/initiators connected to the firing circuit at its permissible maximum resistance.

R3.7.2: If within a firing system 2 or more similar detonators or initiators are connected in series, the maximum time to ignition (irreversible start of the initiation process) of the detonators or initiators shall be shorter than the minimum reaction time (time to detonation) of the detonators or initiators at the minimum output of the exploder.

**R3.8: The detonators and initiators used shall be isolated from subsequent (downstream) elements until on-site assembly and shall be capable of being incorporated into the explosive train at the last moment.**

R3.8.1: The users instructions shall state that the detonators/initiators shall only be connected to downstream explosive stores after their connection to the firing stimulus relay system (connection to the electrical circuit or insertion of safety fuze).

R3.8.2: When using remote control initiation, e.g., radio control or coded signal, the users instructions shall state that the detonators/ initiators shall be connected to the receiver before connection to the explosive charge.

#### **4. FUZES AND FUZING SYSTEMS**

**R4.1: Fuzing systems shall comply with STANAG 4187 and AOP-16 [b3].**

**R4.2: When a activation, deactivation and/or neutralisation capability is specified it shall be performed by processes which are as independent as possible from those which initiate the system.**

**R4.3: For demolition fuzing systems which have a physical break within the firing control system, the system shall conform to the following additional principles.**

R4.3.1: The firing signal generator shall incorporate a safety feature which prevents generation of a firing signal during deployment.

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R4.3.2: Where a safe distance between the explosive charges and the firing signal receiver cannot be maintained, a minimum arming delay between commit-to-arm and armed shall be specified. The system shall be so designed that no single event can cause arming until the specified minimum arming delay, after commit-to-arm, has expired. See §8.3.3e.

**5. ANCILLARY DEMOLITION EQUIPMENT**

**R5.1: Test sets shall not be able to generate controlled nor uncontrolled stimuli greater than the no-fire threshold of the stores which can be connected to it.**

R5.1.1: There should be a safety margin of at least factor 10 (or 1 dB) between these two levels.

**R5.2: Tools, used as prescribed in the user instructions, shall not compromise safety or reliability of the demolition. (s,r)**

**R5.3: Launch tubes and propulsor casings shall be able to withstand the internal pressure of the propellants combustion.**  
(For line charges or mine clearance systems)

**6. ENVIRONMENTAL ASPECTS**

**R6.1: Demolition systems, subsystems, stores and accessories shall be designed to ensure and maintain the required degree of reliability and safety under all environmental conditions likely to be encountered over the life cycle. Moreover, safety shall be ensured and maintained under all extreme but credible environmental conditions.**

R6.1.1: The no function (no-fire) thresholds of any element of the demolition system shall be greater than any kind of stimulus:

- from the expected environments (c.f., [a7] and [c11]) and
- from any signal, induced in or transmitted by the system if it is not to function.

R6.1.2: The design of electrical subsystems, EED and their associated components part of the system should ensure a minimal risk of inadvertent initiation of EED or explosives due to electromagnetic radiation (EMR), electrostatic discharge (ESD), transient and steady state electromagnetic interference (EMI), lightning and nuclear weapon effects C.f., [a7], [c1], [c4] through [c7] and [c11]. (See also R6.2.2d below.)

R6.1.3: The choice of the design of demolition stores, and where appropriate their confinement, packaging and fitments, should minimize the potential of inadvertent initiation and the violence of reaction to external aggressions (sympathetic detonation, initiation due to accidents or hostile acts). C.f., [a7], [a8] [c..]-series.

**R6.2: The life cycle and the predicted service environments shall be defined, based on environmental analyses (c.f. §11) and shall include the conditions stipulated below:**

R6.2.1: With regard to suitability for service, of demolition systems, subsystems, stores and accessories, the “normal” service environment shall include:

- a. The environmental conditions to which the munition is likely to be submitted during its service life (“anticipated normal” environment).
- b. The climatic storage and use conditions, corresponding with the climatic categories defined in STANAG 2895 [c2]. They shall include all climatic categories unless otherwise specified in the requirements. They are further to be determined from measurements or other sources and/or life cycle environmental analysis in accordance with AECTP-100 [a7] and AECTP-200 [c11]. Solar radiation is likely to cause higher temperatures in the deployed demolition stores.
- c. Exposure of the unpackaged article to the open air in the anticipated deployment configuration and situations, for at least 30 days, to include exposure to: rain, wind, freezing, salt air (munitions for land service).
- d. Immersion, of the unpackaged item, in the deployment configuration, as determined in the staff requirements, or, if unspecified:
  - at 2 m of water for 24 h, munitions for land service only;
  - at 10 m of water for 30 days, where the role of the munition includes underwater operations. (See also AECTP-200 [c11]).
- e. Basic transportation vibration and shock, as stipulated in AECTP-1 [c3], AECTP-200 [c11] and for some specific environments AECTP-400 [c11] and STANAG 4242 [c10], for a duration determined in the staff requirements, or, if unspecified covering at least:
  - 1000 km wheeled vehicle transportation;
  - 240 km loose cargo transportation;
  - air cargo transportation by helicopter for 5 h duration, and by fixed wing aircraft for 20 h duration
- f. Handling and human failures during deployment, dismantling or disposal, to be determined from life cycle analysis.

R6.2.2: With regard to the safety of demolition systems, subsystems, stores and accessories, the service environment shall comprise all extreme but credible environmental conditions:

- a. The expected normal and extreme, but plausible, environmental conditions to which the munition is likely to be submitted during its service life (“worst case conditions”).
- b. The “normal” conditions specified under R6.2.1, items b through f above.
- c. The threats mentioned in STANAG 4439 and AOP-39 [a8] to the degree as judged relevant by the National Authority. In particular the following should be considered:
  - fast and slow heating (STANAGs 4240 [c8] and 4382 [c13]);
  - bullet impact (STANAG 4241 [c9]); and
  - drop (STANAG 4375 [c12]).
- d. EMR, electrostatic discharge, lightning and nuclear weapon effects - (N)EMP: STANAGs 1307 [c1], 4234 [c5], 4235 [c6], 4236 [c7] and 4145 [c4].

